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TITLE - Probability of Exceeding Design Wind for Saturn V Freestanding on the Pad

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FILING CASE NO(S) - 310

DATE - June 28, 1966

FILING SUBJECT(S) - (ASSIGNED BY AUTHOR(S) -
KSC Surface Wind Statistics
Launch Environment
Exposure Period
Probability

ABSTRACT

The extreme surface winds that might effect the Saturn V freestanding on the pad are considered. The types of information available and latest statistics about extreme surface winds at KSC are summarized from MSFC papers. The surface wind measurements dealt with are the steady-state, the peak, the daily peak and the maximum peak surface wind speeds. Precautions to avoid misuse of the statistical predictions are pointed out.

The design specification wind speed for the Saturn V freestanding on the pad is 20.7 m/sec (the 99.9 percentile peak surface wind). Interpretation of the surface wind statistics leads to the following conclusions. The probability of exceeding the design wind speed during the strongest wind month is:

1) 0.1% within two minutes
2) 2.6% within a day
3) 24% within 15 days.

If the design wind speed were 24.5 m/sec (the 99.99 percentile peak surface wind), the probability would be reduced to:

1) 0.01% within two minutes
2) 0.61% within a day
3) 6.4% within 15 days.

There is a large seasonal variation of this probability, so that the probability during some months of the wind exceeding 20.7 m/sec may be as much as 65% less than the values given and the probability of exceeding 24.5 m/sec may be as much as 90% less than the values given. Also wind conditions change from day to day almost as if they were independent.

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SUBJECT: Probability of Exceeding Design Wind for Saturn V Freestanding on the Pad Case 310

DATE: June 28, 1966

FROM: D. G. Estberg

TM - 66-2013-2

TECHNICAL MEMORANDUM

INTRODUCTION

~~This memorandum deals~~ with the extreme surface winds at KSC that might effect the Saturn V freestanding on the pad. The types of information available about extreme surface winds are reviewed and latest statistics for KSC are summarized from MSFC papers. The most important of these results is the probability that surface winds will exceed the design specification wind speed for the Saturn V space vehicle freestanding on the pad as a function of days on the pad.

TYPES OF SURFACE WIND MEASUREMENTS

Before discussing wind statistics, several definitions, as used by meteorologists at MSFC, must be given.

Steady-State Surface Wind Speed - The steady-state surface wind speed (also called the quasi-steady-state wind speed) is the average wind speed over a period of two minutes (Reference 3, p. 5.1 and Reference 13). This speed is the basic climatological surface wind measurement. It is recorded hourly at weather observing stations with fixed cup-type or propeller-type anemometers. Note that this sample is for only two minutes out of sixty and it is not truly random, so statistical predictions based on this data may contain rather large sampling errors.

Peak Surface Wind Speed - The peak surface wind speed is the maximum wind speed that occurs for a duration of at least two seconds within the two minute period over which the steady-state wind speed is taken (Reference 7, p. 4). In practice, the peak surface wind speed is found by multiplying the steady-state wind speed by a gust factor of 1.4. This gust factor was originally based on observations at other sites which are comparable to KSC (Reference 7, p. 4 and Reference 12), but since then it has been verified empirically at KSC (Reference 10).

Daily Peak Surface Wind Speed - The daily peak surface wind speed is the daily maximum instantaneous wind speed as determined by a continuously recording instrument (Reference 5, p. 3). When making a statistical analysis of daily peak surface wind, adjustments of the data are made for hurricane associated peak winds and for missing data. If a hurricane is in the vicinity during a day when the peak wind speed is greater than the 99th percentile peak wind speed for the month, then this 99th percentile wind speed is taken as the peak wind speed for the day. For days when continuously recording instrument measurements are not available, the maximum of hourly measurements made during the day is used. The hourly measurement used for this is the observed gust if it is available, but this is recorded only if the gusts reach 8.2 m/sec and the variation between peaks and lulls is at least 4.6 m/sec. If this is not available, then the steady-state wind speed is used.

Maximum Peak Surface Wind Speed - The maximum peak surface wind as defined below is used in the design of facility structures. For example, the Apollo Program Specification (Reference 1, p. 57) requires that the mobile service structure for launch complexes 34 and 37B provide protection for the Saturn IB space vehicle during maximum peak surface wind conditions given in the Natural Environment and Physical Standards for the Apollo Program (Reference 6). The maximum peak surface wind is defined as the 95th percentile wind speed from the cumulative frequency distribution of the annual maximum of the fastest mile wind speed (Reference 11). The fastest mile wind speed is the daily maximum of about one minute average wind speeds taken throughout the day. (The term "fastest mile" comes from the method of taking the average: anenometers record how much air has passed through them in distance; the time for one mile to pass is taken and the fastest mile for the day is recorded.) When finding the annual maximum of the fastest mile wind speed, hurricane associated winds are included, but tornado associated winds are excluded. (A hurricane is a large-scale cyclonic storm which originates over the ocean and has winds of at least 33.4 m/sec (65 knots) but rarely exceeding 80 m/sec; a tornado is a violent whirling wind accompanied by a funnel-shaped cloud that progresses in a narrow path and has winds estimated at 45 m/sec to more than 135 m/sec--even in regions where tornadoes are most common, there is less than 0.1% chance that any given square mile will be struck in any one year.) The maximum peak surface wind speed for KSC is 42.6 m/sec at 9.1 m above the ground (Reference 6, p. 16). Since this is the 95th percentile wind speed, there is a 5% chance, or 1 chance in 20, that the annual maximum wind speed will exceed 42.6 m/sec. It is sometimes said then that the mean return period of the maximum peak surface wind is 20 years, but this can be misleading because it can be shown by methods used below* that during any 20 year period there is a 64% chance that this would be the maximum wind speed recorded and that one would have to wait 90 years before there would be a 99% chance that this would be the maximum.

MODES OF PRESENTING WIND STATISTICS

Wind statistics for each month or for all data combined are usually presented by giving the wind speed that corresponds to each percentile. For example, if the 95th percentile wind speed is 16.3 m/sec, this means there is a 95% chance that the wind speed will not exceed 16.3 m/sec and a 5% chance that it will exceed this value. Another mode of presentation is to give the wind speed during the strongest wind month that corresponds to each percentile. This is obtained by the following method. Data for each month is grouped together, and then all the January's, February's, etc., for the years that data is available are grouped together. For each of these twelve groups (one for each month), frequency distributions and the wind speed corresponding to each percentile are found. Wind speeds higher than the wind speed corresponding to a certain percentile have a greater chance that they will not be exceeded than given by the percentile; therefore, if for each percentile the maximum wind speed over the twelve groups is taken, a conservative value is found, which is the wind speed during the strongest wind month corresponding to that percentile. Thus, for example, the 95th percentile wind speed during the strongest wind month will be greater than the true 95th percentile wind speed found by combining all the data, but it allows for seasonal variation in that during any month of the year there is at least a 95% chance that it will not be exceeded. (Note that the wind speed during the strongest wind month corresponding to each percentile may equivalently be obtained by the following method: for each month find the percent probability that a given wind speed will not be exceeded, then take the minimum of these probabilities over the twelve months; the given wind speed will be the wind speed during the strongest wind month corresponding to the percentile whose numerical value has been obtained as a percent probability.)

Care must be taken in using the statistical distributions of the different types of wind measurements. Important points that have not been considered elsewhere in this paper are as follows:

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*See equation 1, p. 6.

1. The basic assumption made is that past distributions can be used to predict future distributions.

2. In any particular application of wind statistics, the additional effects of terrain features and of adjacent structures should be considered.

3. The duration of the extreme winds should be considered. The peak wind speed and the daily peak wind speed dealt with here include gusts that may last only two seconds.

4. It is important to realize that the distribution of peak surface wind speed measurements can only be used to predict the probability of exceeding a given wind speed within any two minute period--the probability that it will be exceeded in a longer time interval will be higher. For example, the 99.9 percentile peak surface wind speed during the strongest wind month at 9.1 m above the ground at KSC is 20.7 m/sec. Therefore, there is a 0.1% chance that there will be wind greater than 20.7 m/sec within any two minutes. However, the probability during the strongest wind month that a wind speed will exceed 20.7 m/sec within any hour is about 0.7% and within any day (24 hours) is 2.6%. The 0.7% value is taken from Reference 9, Table 3; this table was obtained by developing scaling factors based on empirical analysis of daily peak wind distributions. The 2.6% value is obtained from the daily peak wind ~~distribution and is~~ derived in the next section. The conclusion to be drawn is that the 0.1% value obtained from peak surface wind statistics is of little value when it is desired to find the probability that the wind will exceed a certain speed within an extended time interval.

WIND STATISTICS FOR KSC

Distribution of Surface Winds - All surface wind speeds given here are for a 9.1 m (30 ft) reference height above the ground. Wind speeds are given in meters per second and knots; the meters per second value can be converted to miles per hour by multiplying by 2.236 and to feet per second by multiplying by 3.281. In Figure 1, four wind distributions are shown:

1. The steady-state wind speed during the strongest wind month as given in the Natural Environment and Physical Standards for the Apollo Program (Reference 6, pp. 17 and 84b; see also References 4 and 8).

2. The peak wind speed during the strongest wind month as obtained by multiplying the steady-state wind speed by the gust factor of 1.4.

3. The daily peak wind speed as given in Reference 5, Table I.17.

4. The daily peak wind speed during the strongest wind month as determined by the upper envelop of the daily peak wind speeds for each month given in Reference 5, Tables I.1 - I.12.

<u>Exposure Period Probabilities</u> - The <u>Apollo Program Specification</u> (Reference 1, p. 19) states, concerning the Saturn V launch vehicle structure, that "...the space vehicle shall have a freestanding capability, with the propellant containers pressurized or unpressurized, on the launch pad during the 99.9 percentile peak surface wind conditions given in..." Reference 6. This wind speed is 20.7 m/sec (40.2 knots) at 9.1 m above the ground. The probability that the surface winds equal or exceed the design speed as a function of days on the pad is called the exposure period probability. It is also of interest to consider the exposure period probabilities if the design capability were the 99.99 percentile peak wind which is 24.5 m/sec (47.6 knots); this value is obtained by extrapolation of the curve for the peak wind speed during the strongest wind month in Figure 1.

The exposure period probability as a function of design wind speed, W^*, and number of days on the pad, n, will be denoted by $P_n(W \geq W^*)$. This notation will be used when the data for all months is combined to get the probability (as it is for the daily peak wind speed distribution) and a prime will be added when data for the strongest wind month is used. The exposure period probabilities for one day can read from Figure 1 as

$$P_1(W \geq 20.7) = 1.1\%$$

$$P_1'(W \geq 20.7) = 2.6\%$$

$$P_1(W \geq 24.5) = 0.22\%$$

$$P_1'(W \geq 24.5) = 0.61\%.$$

The value for $P_1'(W \geq 20.7)$ is the one quoted in the previous section. In Reference 5, $P_n(W \geq W^*)$ and $P_n'(W \geq W^*)$ for $1 \leq n \leq 30$ and a large range of W^* have been emperically determined; in Reference 9, these results for $W^*=20.7$ have been extended to 90 days. These results for $W^*=20.7$ and 24.5 are shown in Figure 2.

Also given in Figure 2, as a comparison to $P_n(W \geq 20.7)$, is a theoretical curve assuming that wind conditions are independent from day to day, which gives the maximum estimate of the exposure period probability. The equation for the theoretical curve is

$$P_n(W \geq 20.7) = 1 - [1 - P_1(W \geq 20.7)]^n \quad (1)$$

where fractional probabilities are now used. This gives the probability of having winds ≥ 20.7 m/sec at least once during n days, which is the probability of not having winds <20.7 m/sec on all of the n days. Note, from equation (1), that $P_n'(W \geq W^*)$ may be conservatively estimated by

$$P_n'(W \geq W^*) \approx n\, P_1'(W \geq W^*).$$

This estimate is quite close for $P_1'(W \geq W^*)$ very small and Figure 2 shows that the emperical and theoretical curve are reasonably close. Therefore, this relation, along with the curve for ~~the daily peak~~ surface wind during the strongest wind month (Figure 1), may be used either to go from a given design wind speed to an exposure period probability or to go from a desired exposure period probability to a design wind speed.

Exposure period probabilities may also be found for each month; the exposure period starts on any day during the given month. Monthly exposure period probabilities are given in References 5 and 9, and these results are reproduced in Figure 3. First notice that there is a large variation of exposure period probability with month, so the exposure period probability during the strongest wind month greatly overestimates the exposure period probability during certain months; it is seen from Figure 3 that $P_{15}(W \geq 20.7)$ may be as much as 65% less than $P_{15}'(W \geq 20.7)$ and $P_{15}(W \geq 24.5)$ may be as much as 90% less than $P_{15}'(W \geq 24.5)$. Next, comparing $P_{15}(W \geq 20.7)$ and $P_{15}'(W \geq 24.5)$, for example, it is noticed that the most favorable and unfavorable months do not always agree; this is caused by the storms characteristic of a certain month usually having winds within a certain speed interval. Thus, all that can be concluded from the figure is that January and February are the most favorable months and March is the least favorable month.

CONCLUSIONS

The peak surface wind distribution is of little value in determining the probability that the design specification wind speed for the space vehicle freestanding on the pad will be exceeded. This gives a probability which is significantly lower than obtained from the daily peak surface wind distribution. For a design wind speed of 20.7 m/sec (99.9 percentile) at 9.1 m above the ground, the correct probability during the strongest wind month is about 2.6% for one day on the pad and increases to about 24% for 15 days on the pad. If the design wind speed were 24.5 m/sec (99.99 percentile), the probability would be reduced to about one fourth these values. The increase of exposure period probability with days on the pad is not greatly different than what would be expected if the wind conditions from day to day were independent. The above probabilities are for the strongest wind month during the year; since there is a seasonal variation in exposure period probabilities the probabilities during any given month may be much lower than these values.

D. G. Estberg

2013-DGE-mkm

Attachment
References
Figures 1-3

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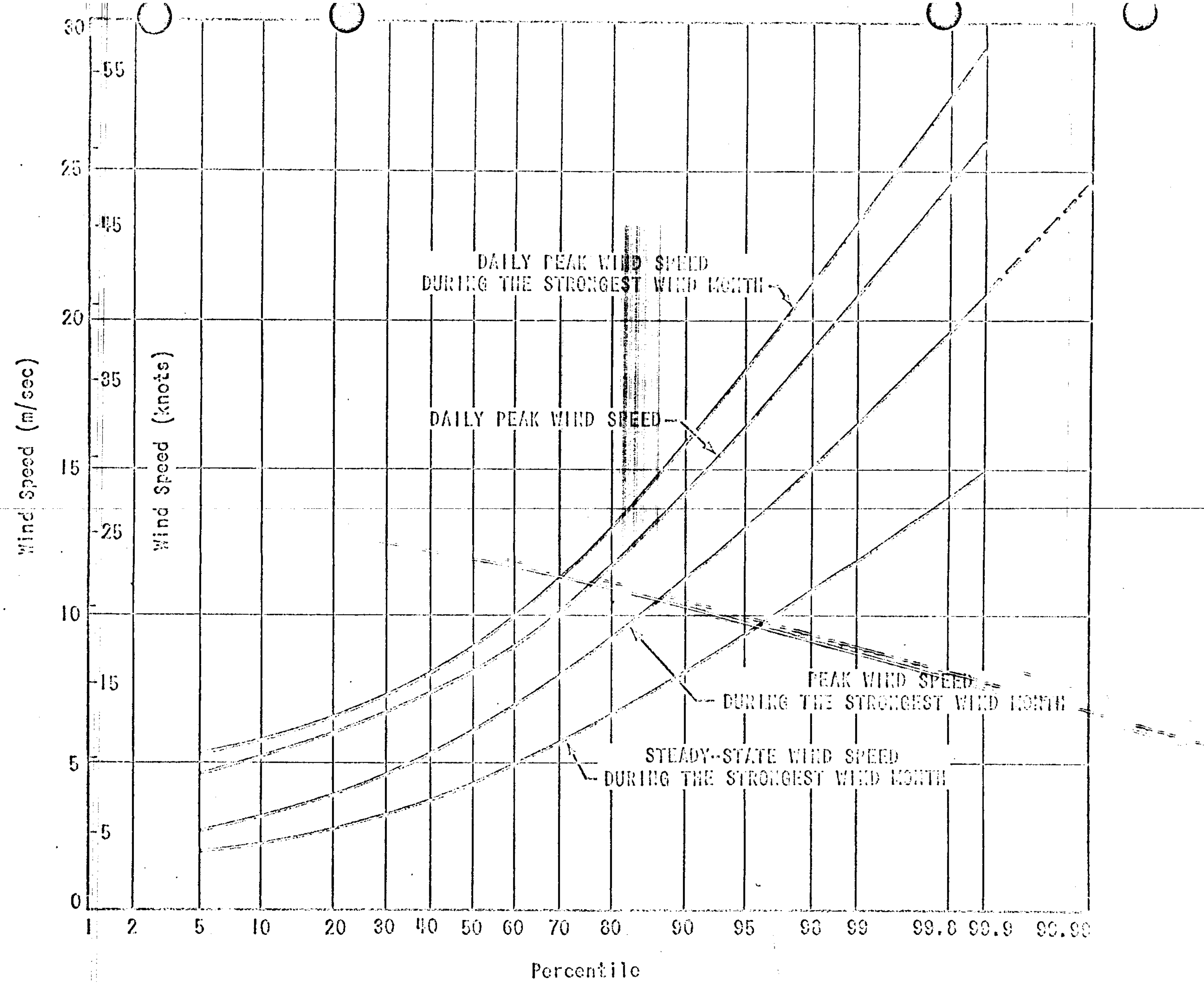

FIGURE 1 - DISTRIBUTION OF SURFACE WIND SPEEDS AT 9.1 M (30 FT) ABOVE THE GROUND

(REFERENCES 3, 5 AND 6)

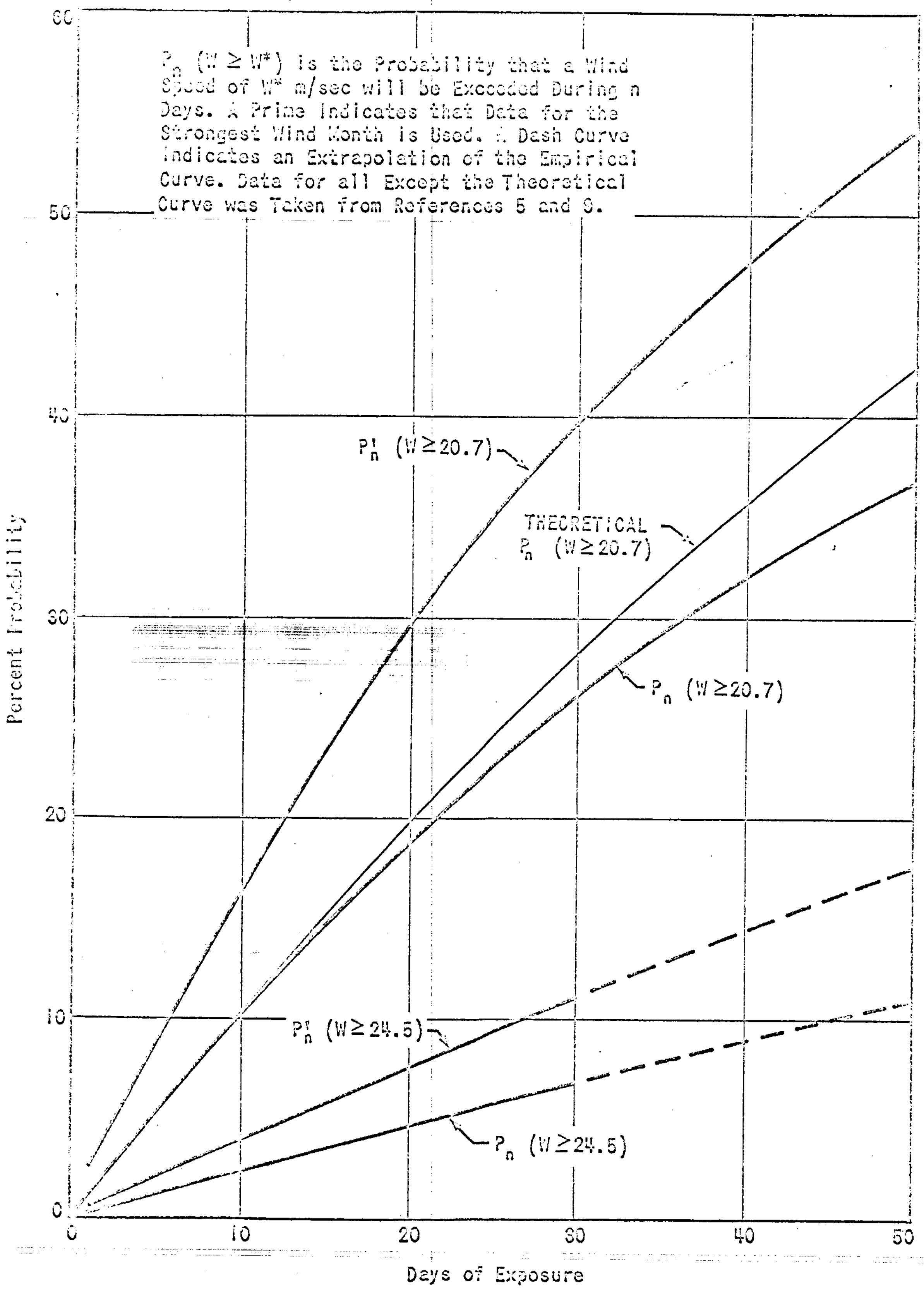

FIGURE 2 - EXPOSURE PERIOD PROBABILITIES

(PROBABILITY THAT THE DESIGN WIND WILL BE EXCEEDED AS A FUNCTION OF DAYS ON THE PAD)

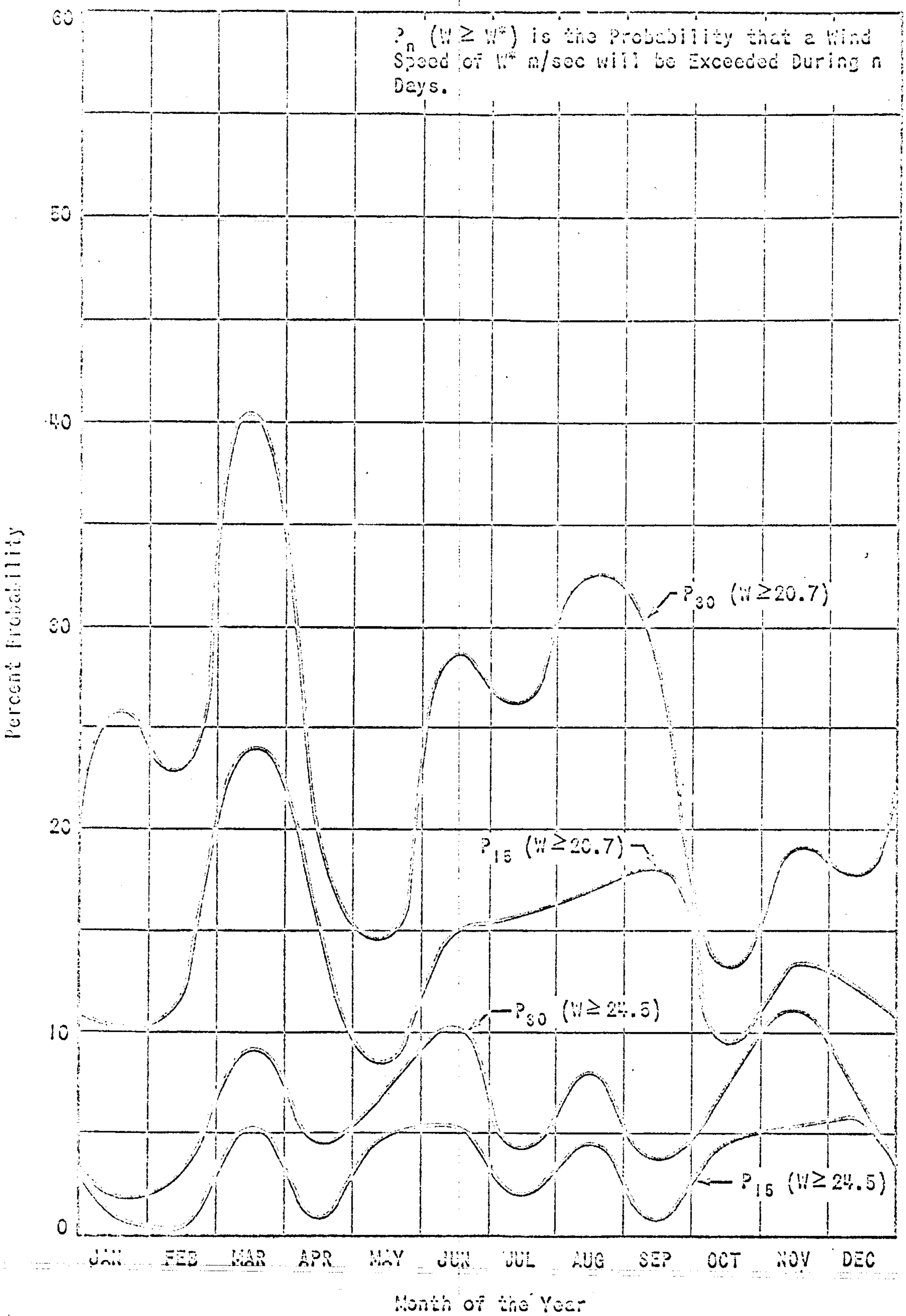

FIGURE 3 - VARIATION OF EXPOSURE PERIOD PROBABILITY WITH MONTH

(REFERENCES 5 AND 6)

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